Amendments to the Specification:

Please insert a new heading and paragraph before the heading "BACKGROUND" on page 1 as follows:

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. Patent Application No. 09/872,495, entitled "Quantum Processing System for a Superconducting Phase Qubit," filed June 1, 2001, which is hereby incorporated by reference in its entirety.

Please replace the paragraph on page 9, beginning "Figures 2 shows" with the following amended paragraph:

Figure 2 shows qubit 100 coupled with a control system 800. Control system 800 can be coupled to bulk superconductor 110, for example through line 801, and to island 120, for example through line 802. ~~Controller~~ Control system 800 can provide currents through qubit 100 and can ground qubit 100 in order to read the quantum states of qubit 100 or initiate quantum states of qubit 100.

Please replace the final paragraph on page 9, beginning "Controller 800 can read out" with the following amended paragraph:

~~Controller~~ Control system 800 can read out the state of qubit 100 by grounding qubit 100, applying a current across qubit 100, measuring a voltage across qubit 100, and interpreting the quantum state of qubit 100 based on the measured voltage. When the quantum state of qubit 100 is evolving quantum mechanically, the states of qubit 100 are in a superposition of the two degenerate quantum states. When qubit 100 is grounded, the wavefunction collapses into one of the two available degenerate basis states. As a current is applied across qubit 100 the flux, which defines the basis state (i.e., either the $|0>$ or $|1>$ basis states) of qubit 100, changes from a ground state to an excited state. Since voltage is dependent upon the derivative of the flux with respect to time, a voltage results that is dependent upon the state of qubit 100 at the time of grounding. If the flux (qubit state) occupies a first state at the time of grounding, then a set of voltage pulses can be detected, whereas, if

the flux occupies a second state at the time of grounding, a single voltage pulse will result. Moreover, the detectable voltage pulses [a] can be resolved in time, thus illuminating a method for differentiating between the states of the qubit.

Please replace the paragraph on page 11 that begins with "Therefore, controller 800 can readout the" with the following amended paragraph:

Therefore, ~~controller~~ control system 800 can ~~readout~~ read out the quantum state of qubit 100 by grounding qubit 100 (i.e., coupling island 120 to ground), applying a bias current across qubit 100, the bias current being of a magnitude between the critical currents associated with the quantum states of qubit 100, and measuring the potential drop across qubit 100.

Please replace the paragraph on page 11 that begins with "Qubit control system 800 of Figure 2" with the following amended paragraph:

Qubit control system 800 of Figure 2, then, can include circuits for reading out the quantum state of qubit 100. Qubit control system 800 can have one control branch 801 coupled to bulk superconductor 110, and a second control branch 802 coupled to island 120 of qubit 100. ~~control~~ Control system 800, then, can perform a readout procedure by grounding qubit 100 through control line 802, applying a current to bulk superconductor 110 through control branch 801, and measuring the potential drop across control branch 801 and the qubit branch 802. The current is a supercurrent of Cooper pairs. Thus, synchronized with the application of current to grounded qubit 100, control system 800 measures the voltage across qubit 100. Control system 800 then interprets the measured potential drop as indicating one of the possible states of qubit 100. Control system 800 can then communicate the measured quantum state of qubit 100 to another system (not shown) that interfaces with qubit control system 800.

Please replace the paragraph on page 12 that begins with "Figure 3 shows an embodiment" with the following amended paragraph:

Figure 3 shows an embodiment of a qubit array 300 with control system 800 coupled to qubit array 300. Qubit array 300 includes qubits ~~qubitss~~ 100-1 through 100-N. As described above, a single control branch 801 is coupled to superconducting substrate 110, which is common to qubits 100-1 through 100-N. Qubit branches 802-1 through 802-N are coupled to islands 120-1 through 120-N, respectively. ~~Controller~~ Control system 800 can perform readout procedures as described above on each of qubits 100-1 through 100-N. In some embodiments, during a readout procedure on one of qubits 100-1 through 100-N, the qubit being read is grounded while the remaining ones of qubits 100-1 through 100-N are not grounded. The potential drop taken across control branch 801 and the grounded qubit branch can be measured and interpreted by control system 800 in order to determine the quantum state of the qubit being read.

Please replace the paragraph on page 13 that begins with "In some embodiments switch 130 can be a single" with the following amended paragraph:

In some embodiments switch 130 can be a single electron transistor or parity key that can couple island 120 to ground. By modulating the voltage on the single electron transistor (SET)s, control system ~~circuit~~ 800 can open or close the grounding connection. The behavior of SETs is well defined and is discussed in detail in P Joyez et al., "Observation of Parity-Induced Suppression of Josephson Tunneling in the Superconducting Single Electron Transistor," Physical Review Letters, Vol. 72, No. 15, 11 April 1994, herein incorporated by reference in its entirety.

Please replace the paragraph on page 14 that begins with "A readout method using" with the following amended paragraph:

A readout method using the embodiment of control system 800 shown in Figure 4 includes grounding qubit 100 through grounding switch 130, applying a bias current through current source 140, measuring the potential drop across qubit 100 in voltmeter 150, and interpreting the measured potential drop to determine the quantum

state of qubit 100. In some embodiments, voltmeter 150 may [by] <u>be</u> calibrated to output directly the measured quantum state of qubit 100. In some embodiments, other portions of control system 800 are calibrated to receive the voltage measurement from voltmeter 150 and determine the quantum state of qubit 100.

Please replace the paragraph on page 14 that begins with "Figure 5 shows an example of" with the following amended paragraph:

Figure 5 shows an example of an array of qubits 300 coupled to an embodiment of ~~controller~~ <u>control system</u> 800. Each of qubits 100-1 through 100-N in qubit system array of qubits 300 is coupled to a grounding switch 130-1 through 130-N, respectively, by which each of qubits 100-1 through 100-N can be selectively coupled to ground 131 when ~~controller~~ <u>control</u> system 800 closes switch 130-1 through 130-N, respectively. Furthermore, as in the single qubit case shown in Figure 4, current source 140 is coupled between bulk superconductor 110 and ground 131. Voltmeter 150 is coupled in parallel with qubits 100-1 through 100-N between bulk superconductor 110 and ground 131.

Please replace the last paragraph on page 15 that begins with "In some embodiments of the invention, control system 800 also initializes the quantum states of qubit 100-1" with the following amended paragraph:

In some embodiments of the invention, control system 800 also initializes the quantum states of qubits 100-1 through 100-N in qubit system 300. A method for initializing the state of a qubit 100 (an arbitrary one of qubits 100-1 through 100-N) includes driving a current across the qubit in a specific direction and ramping the current down to zero. The bistability of the ground state in qubit 100 occurs when the bias current through qubit 100 is reduced to zero, where the classical quantum states of qubit 100 ~~corresponds~~ <u>correspond</u> to $\pm\Phi_0$. Thus, by driving a current across qubit 100 in a particular direction, a first state can be selected, and by driving a current across qubit 100 in the reverse direction a second state can be selected. When the

current is ramped down to zero from the positive direction, the flux state of qubit 100 will relax into the $+\Phi_0$ ground state. Whereas, if the current is ramped to zero from the negative direction, the flux state of qubit 100 will relax into the $-\Phi_0$ ground state. Since the states $+\Phi_0$ and $-\Phi_0$ correspond to the bistable ground states of qubit 100, the action of placing qubit 100 into one or the other of the states is equivalent to initializing the state of qubit 100.

Please replace the paragraph on page 16 that begins with "An initialization method, then, includes closing switch 130" with the following amended paragraph:

An initialization method, then, includes closing switch 130 to ground qubit 100, applying current from current source 140 to qubit 100 at some magnitude I_b, and then ramping the current from source 140 from magnitude I_b back to zero. In some embodiments, [control circuit] <u>control system</u> 800 applies a positive current I_b to initialize a first state, and applies a negative current I_b to initialize a second state.

Please replace the last paragraph on page 16 that begins with "Figure 7 shows an embodiment of a current source 140" with the following amended paragraph:

Figure 7 shows an embodiment of a current source 140 which is bi-directional. Current source 140, as shown in Figure 7, includes a first current source 141 and a second current source 142. Current source 141 is coupled in series with a switch 143 and current source 142 is coupled in series with a switch 144. The combination of current source 141 and switch 143 is coupled in parallel with current source 142 and switch 144, which is coupled between superconducting substrate 110 and ground 131. Control system 800 can, then, select current source 141, which provides current in a first direction, by closing switch 143 and opening switch 144. Alternatively, [current source] <u>control system</u> 800 can select current source 142, which provides current in a second direction opposite the first direction, by closing switch 144 and opening switch 143. In some embodiments, each of switch 141 and 143 can be a SET.

Please replace the paragraph on page 17 that begins with "Figure 9 demonstrates an embodiment of voltmeter 140 which can be utilized" with the following amended paragraph:

Figure 9 demonstrates an embodiment of voltmeter 140 which can be utilized with ~~controller~~ control system 800. Voltmeter 140 can be a radio-frequency single electron transistor electrometer such as that described in, for example, A. N. Korotkov and M. A. Paalanen, "Charge Sensitivity of Radio-Frequency Single Electron Transistor," Appl. Phys. Lett. 74, 26 (1999), which is herein incorporated by reference in its entirety. The operation and behaviour of SETs is well known, and is described in detail in P Joyez et al., "Observation of Parity-Induced ~~Supression~~ Suppression of Josephson Tunneling in the Superconducting Single Electron Transistor," Physical Review Letters, Vol. 72, No. 15, 11 April 1994, which is herein incorporated by reference in its entirety.

Please replace the paragraph on page 19 that begins with "In some embodiments, controller 800 couples qubits 100-1 and 100-2 for a" with the following amended paragraph:

In some embodiments, ~~controller~~ control system 800 couples qubits 100-1 and 100-2 for a unit duration of time, wherein the unit duration is dependent upon the embodiment of qubits 100-1 and 100-2. In some embodiments, the unit duration can be at least on the order of the tunneling amplitude of qubit system 1000. Where a longer coupling duration is required by a computing algorithm, multiple unit duration entanglements can be combined.

Please replace the paragraph on page 19 that begins with "Figure 11 shows an embodiment of the invention with a qubit array 300" with the following amended paragraph:

Figure 11 shows an embodiment of the invention with a qubit array 300 coupled to a control system 800 where control system 800 can entangle the quantum states of adjacent ones of qubits 100-1 through 100-N. Adjacent pairs of qubits 100-1 through 100-N are coupled through switches 155-1 through 155-(N-1). Qubits 100-1 and 100-2 are coupled through switch 155-1, for example, while qubits 100-(N-1) and 100-N are coupled through switch 155-(N-1). ~~Controller~~ Control system 800 is coupled to each of switches 155-1 through 155-(N-1) so that ~~controller~~ control system 800 can entangle quantum states between adjacent ones of qubits 100-1 through 100-N in response to algorithm program instructions.

Please replace the paragraph on page 20 that begins with "Further, control system 800 in Figure 12 can readout the quantum state of" with the following amended paragraph:

Further, control system 800 in Figure 12 can ~~readout~~ read out the quantum state of qubits 100-1 and 100-2 by opening entanglement switch 155, grounding one of islands 120-1 and 120-2 through grounding switches 130-1 and 130-2, and applying a current from current source 140 while monitoring the voltage across the one of qubits 100-1 and 100-2 being read. Additionally, ~~controller~~ control system 800 in Figure 12 can initialize the states of qubits 100-1 and 100-2 by opening entanglement switch 155, grounding one of islands 120-1 or 120-2, and applying a bias current from current source 140 as described above so that the quantum state of the one of qubits 100-1 and 100-2 being initialized transitions to the desired state.

Please replace the paragraph on page 20 that begins with "Figure 13 shows a qubit array (register) 300 coupled to control system 800" with the following amended paragraph:

Figure 13 shows a qubit array (register) 300 coupled to control system 800. Control system 800 can perform readout operations on each of qubits 100-1 through 100-N, can initialize each of qubits 100-1 through 100-N, and can entangle adjacent pairs of qubits 100-1 through 100-N. Adjacent ones of qubits 100-1 through 100-N

are coupled through entanglement switches 155-1 through 155-(N-1), where the state of each entanglement switch 155-1 through 155-(N-1) can be modulated by voltage sources 160-1 through 160-(N-1), respectively. Any number of pairs of adjacent qubits 100-1 through 100-N can be entangled under the direction of [controller] control system 800 at any given time. [Controller] Control system 800 entangles adjacent pairs of qubits 100-1 through 100-N in response to algorithm instructions which can be communicated to [controller] control system 800.

Please replace the paragraph beginning on page 22 that begins with "In some embodiments, qubits 100-1,1 through 100-N,M can be initialized by" with the following amended paragraph:

In some embodiments, qubits 100-1,1 through 100-N,M can be initialized by initializing each successive column of qubits simultaneously, and progressing across the columns. For example, first a voltage can be applied to the voltage lines $V_{145\text{-}1}$ and $V_{130\text{-}1}$, thus closing the respective qubit switches and grounding switches for every qubit in the first column. Secondly, a current can be applied to each of the current lines $I_{140\text{-}1}$ through $I_{140\text{-}N}$ simultaneously, such that the direction of the current in the respective current line determines the basis state to be initialized. The process can then be repeated for the remaining columns in the grid, thus requiring a total of M steps to initialize the entire qubit system. An embodiment of a method for reading out the state of the grid qubit system, qubits 100-1,1 through 100-N,M, can include grounding the entire system by closing each of switches 100-1,1 through 100-N,M, applying a voltage to one column of qubit ~~switchs~~ switches 145-1,1 through 145-N,M of a column of qubits to be read, applying a current to the respective current line of ~~said~~ the first qubit, measuring the potential drop between the respective current line and grounding lines, and interpreting the state of the qubit that is being read. During calculation, qubits 100-1,1 through 100-N,M in the qubit system can be completely isolated from the surroundings by opening all of switches 145-1,1 through 145-N,M and 130-1,1 through 130-N,M.